Appendix B
(Nutrient Limitation Analysis)

Total Maximum Daily Loads of Nitrogen for Three Tidal Tributaries and Total Maximum Daily Load of Biochemical Oxygen Demand for One Tributary in the Newport Bay System Worcester County, Maryland

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Nitrogen and phosphorus are essential nutrients for algal growth. However, common types of algae require different amounts of these two nutrients. If one nutrient is available in great abundance relative to the other nutrient, then the nutrient that is less available restricts the amount of plant that can be produced, regardless of the amount of the other nutrient that is available. This less available nutrient is called the "limiting nutrient". Before conducting any analysis in terms of reduction, it is necessary to examine the ratio of nitrogen to phosphorus to establish which nutrient is most likely limiting the algal growth in the system.

In general, an DIN:DIP ratio in the range of 7:1 to 12:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the N:P ratio is greater than 12:1, phosphorus tends to be limiting, and if the N:P ratio is less than 7:1, nitrogen tends to be limiting (Wetzel, 2001). However only the DIN:DIP ratio by itself is not sufficient to establish which nutrient will be limiting. The limiting nutrient also depends on the concentration of the nutrients as well as bio-availability of these nutrients. Detailed modeling sensitivity runs are also required to justify which nutrient is most likely limiting under existing and other conditions.

Various field data (MDE, DNR, MCBP, NPKS) were examined to analyze the nutrient limitation in the Newport Bay System. The result was analyzed using a ratio of dissolved nitrogen to dissolved phosphorus concentrations. A detailed analysis is presented in the Table B1 below for both low summer sampling and high winter sampling flow conditions. The table suggests that the low flow system is more likely nitrogen limiting even though sometimes the data show it could be phosphorus limiting. The results from the high flow monitoring data suggest the system is kind of borderline, and it is difficult to draw conclusion as to which nutrient will be limiting. A set of sensitivity tests using the WASP model were also conducted using the critical loads and the flows. The results are presented in Table B2.

Table B1: Nutrient Limitation Analysis from Field Monitoring Data

Summer Sampling Data			**Winter Sampling Data**		
Date	Station	DIN/DIP	Date	Station	DIN/DIP
07/01/1998	AYR0017	2	04/29/1998	AYR0017	3
07/28/1998	AYR0017	1	04/29/1998	AYR0033	132
08/26/1998	AYR0017	0	04/29/1998	KIT0015	30
09/30/1998	AYR0017	4	04/29/1998	NPC0012	19
10/21/1998	AYR0017	4	04/29/1998	TRC0043	11
07/28/1998	AYR0033	2	04/29/1998	XCM1562	4
08/26/1998	AYR0033	3	04/29/1998	TRC0059	59
09/30/1998	AYR0033	3	04/29/1998	XCM1562	4
10/21/1998	AYR0033	30			
07/01/1998	KIT0015	20			
07/28/1998	KIT0015	3			
08/26/1998	KIT0015	26			
09/30/1998	KIT0015	7			
10/21/1998	KIT0015	4			

Summer Sampling Data			Winter Sampling Data		
Date	Station	DIN/DIP	Date	Station	DIN/DIP
07/28/1998	NPC0012	1			
08/26/1998	NPC0012	1			
09/30/1998	NPC0012	2			
07/28/1998	NPC0031	7			
08/26/1998	NPC0031	1			
09/30/1998	NPC0031	2			
10/21/1998	NPC0031	16			
07/01/1998	TRC0043	2			
07/28/1998	TRC0043	0			
08/26/1998	TRC0043	0			
09/30/1998	TRC0043	1			
10/21/1998	TRC0043	1			
08/26/1998	TRC0059	16			
09/30/1998	TRC0059	13			
10/21/1998	TRC0059	4			
07/01/1998	XCM1562	1			
07/28/1998	XCM1562	4			
08/26/1998	XCM1562	0			
09/30/1998	XCM1562	6			
10/21/1998	XCM1562	8			
07/01/1998	XCM3367	3			
07/28/1998	XCM3367	11			
08/26/1998	XCM3367	4			
09/30/1998	XCM3367	5			
10/21/1998	XCM3367	4			
07/01/1998	XCM4878	5			
07/28/1998	XCM4878	5			
08/26/1998	XCM4878	3			
09/30/1998	XCM4878	2			
10/21/1998	XCM4878	4			

The Table B1 above suggests that the system is not likely nitrogen limited in the summer, but it can be either (N or P) limiting in the spring and in the winter. However DIN/DIP ratio itself cannot be sufficient to interpret which is the limiting nutrient. Keeping this in mind, the model was run for different loads of nitrogen and phosphorus for each condition of flow. Initially, the model was run for current loading conditions. Then they were re-run with a double load of phosphorus and a double load of nitrogen separately to see which nutrient affects the system. Similar runs were also conducted to check the impact there would be of cutting the load of individual nutrients (nitrogen or phosphorus) by 50%. Figure B1 and

Figure B2 below presents the impact of doubling the nitrogen load and the phosphorus load individually. The run shows that doubling of nitrogen load changed the algal concentration significantly while doubling phosphorus load had a very little effect. Similar results were obtained when the individual loads were reduced by 50% (Figure B3 and Figure B4). This supports the assumption that the system is nitrogen limited during a low flow condition.

Table B2: Nutrient Limitation Analysis from the Model Results

	DIN/DIP		
WQ Segments	Summer	Spring	Winter
1	1	1	3
2	1	2	5
3	2	3	7
4	2	4	9
5	1	7	10
6	1	9	10
7	1	10	10
8	1	11	10
9	1	10	10
10	0	10	11
11	0	11	11
12	7	14	15
20	1	9	9
21	1	7	8
22	1	6	7
25	2	5	9
26	1	1	9
27	1	1	9

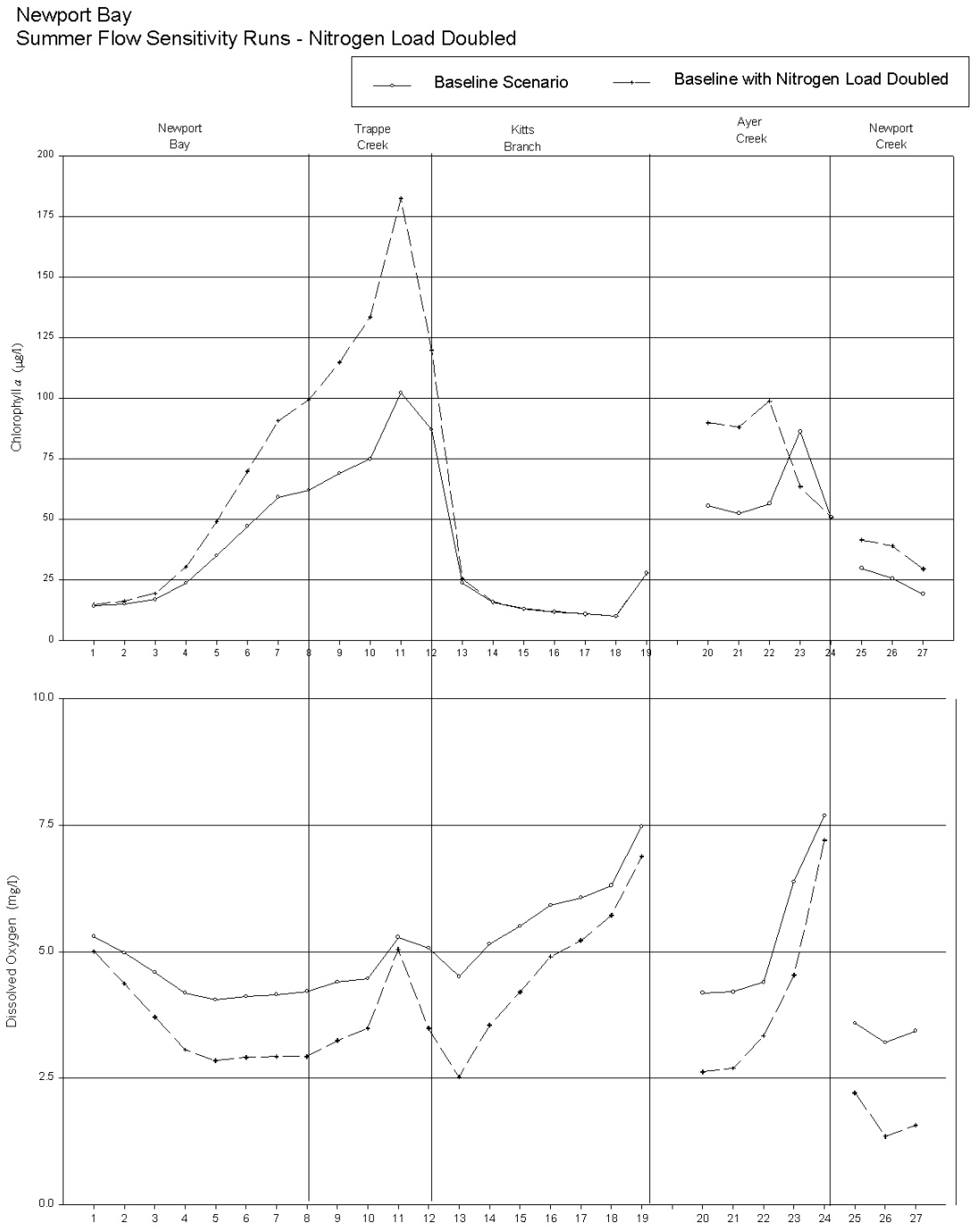

Figure B1: Sensitivity Test of Doubling the Nitrogen Load in the Low Flow Condition

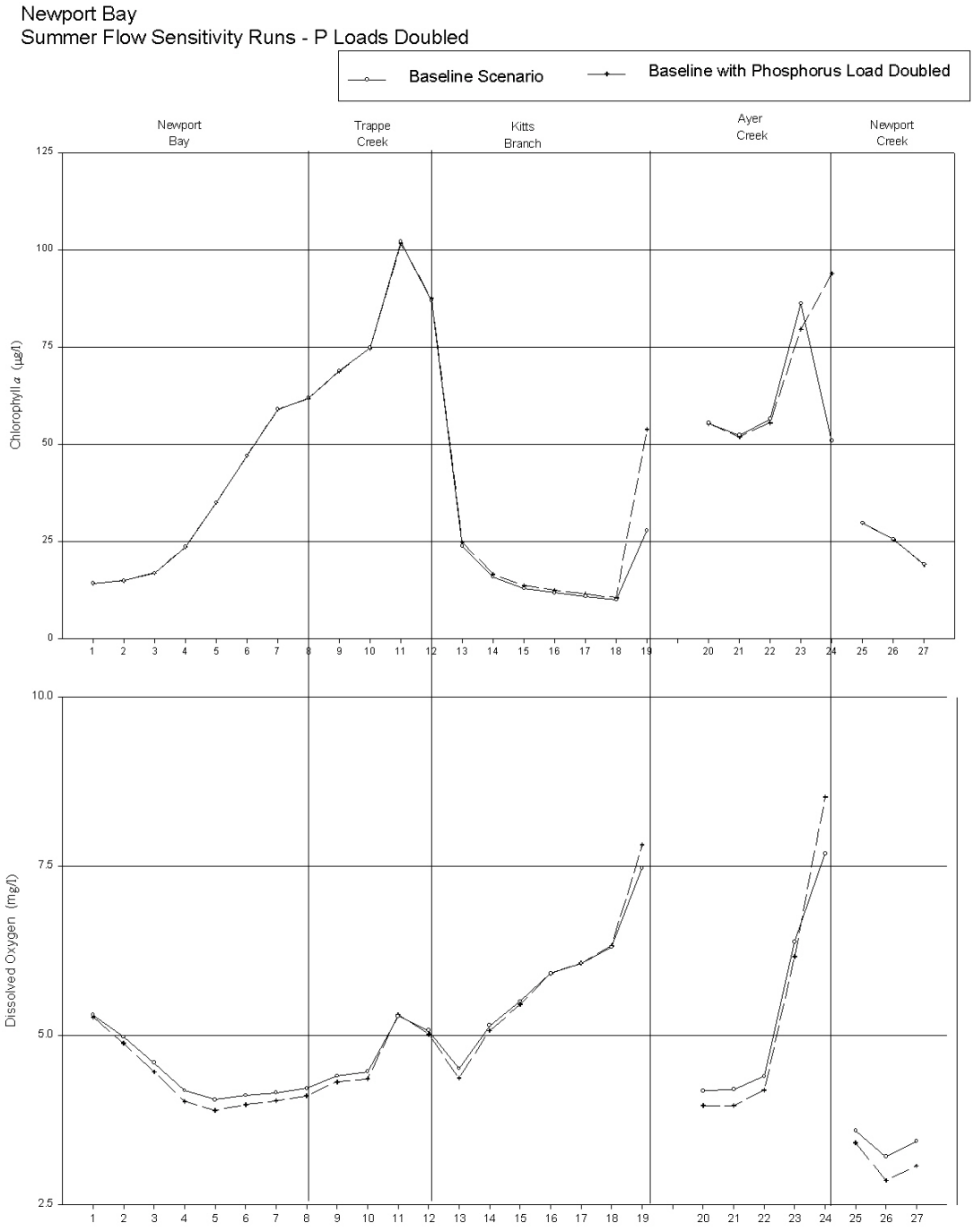

Figure B2: Sensitivity Test of Doubling the Phosphorus Load in the Low Flow Condition

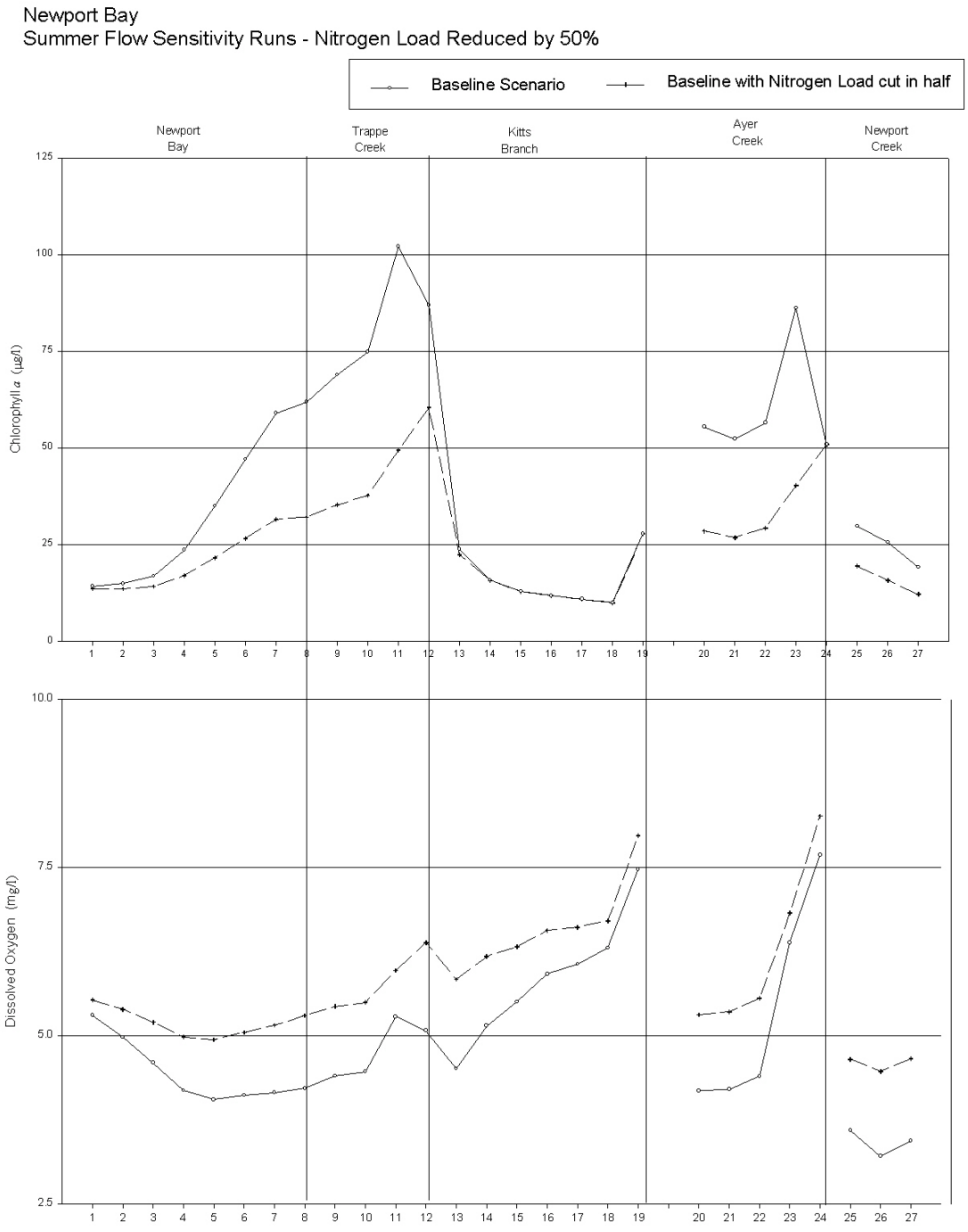

Figure B3: Sensitivity Test of Halving the Nitrogen Load in the Low Flow Condition

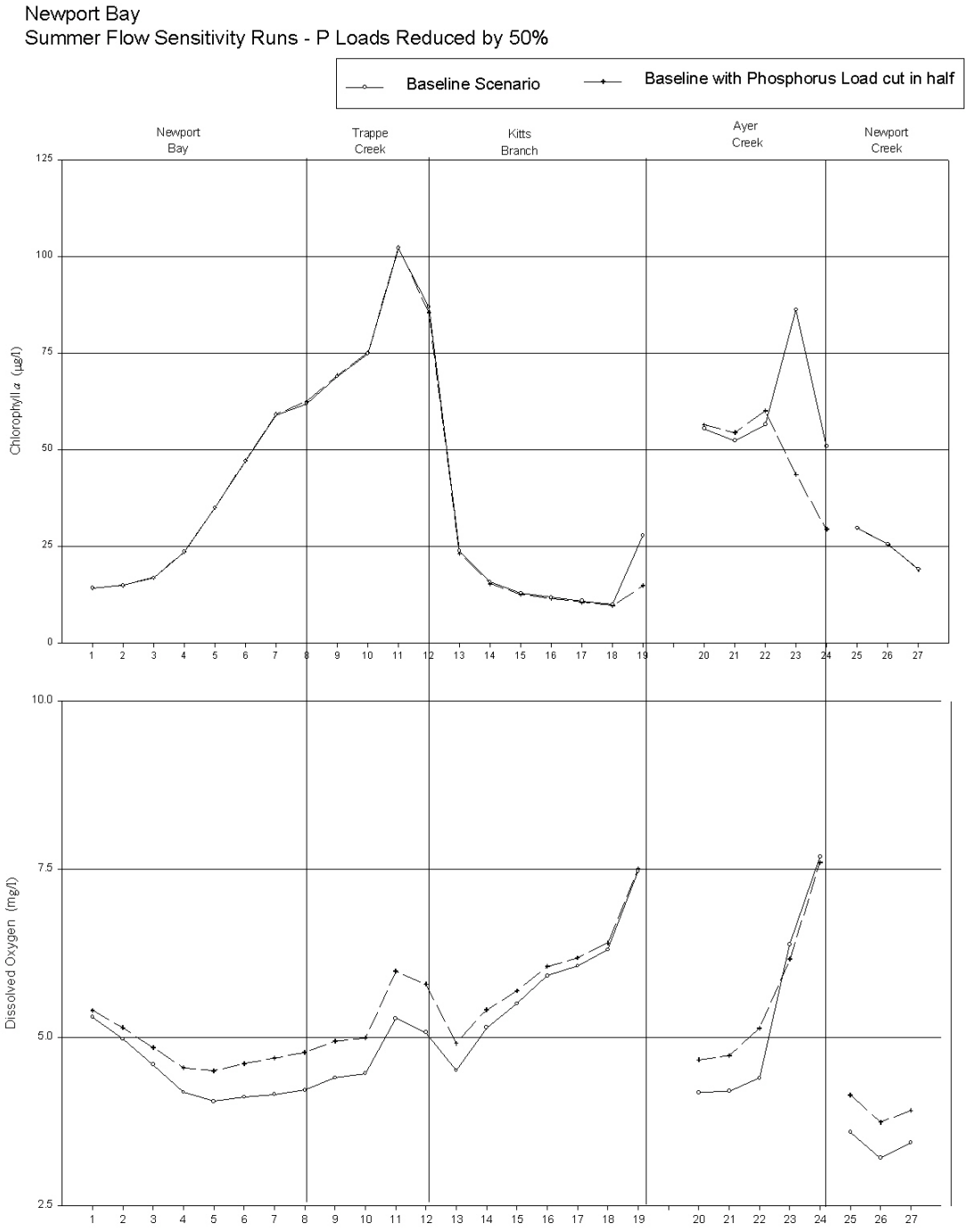

Figure B4: Sensitivity Test of Halving the Phosphorus Load in the Low Flow Condition

Similar runs were conducted for individual nutrients (N or P) for annual average condition of flow to see what would limit the algal growth in the system. Doubling and reducing the nitrogen load by 50% made a significant difference (Figure B5 & Figure B7), while the results were not significant when doubling or reducing to half the phosphorus loads (Figure B6, Figure B8).

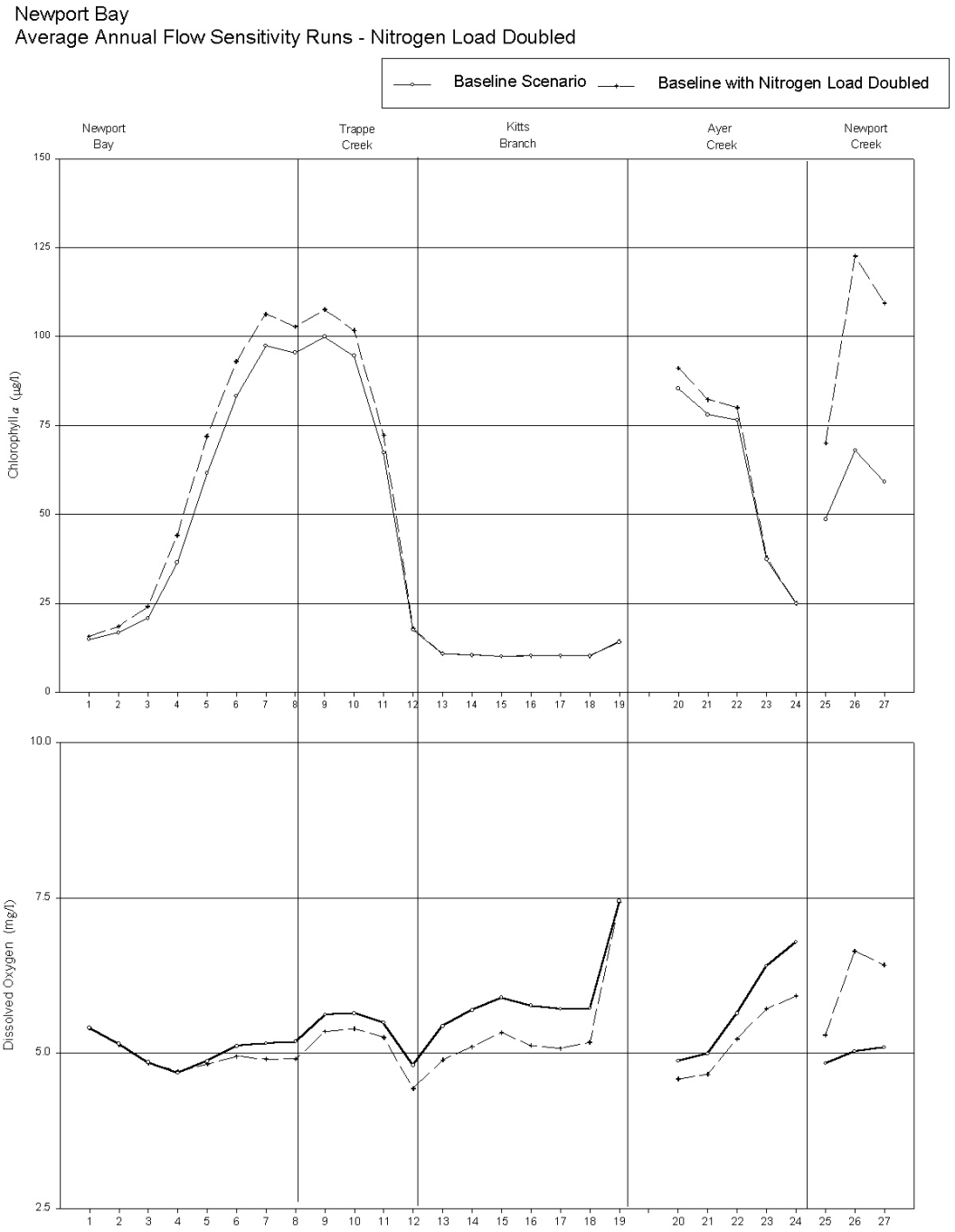

Figure B5: Sensitivity Test of Doubling the Nitrogen Load in the Average Annual Flow Condition

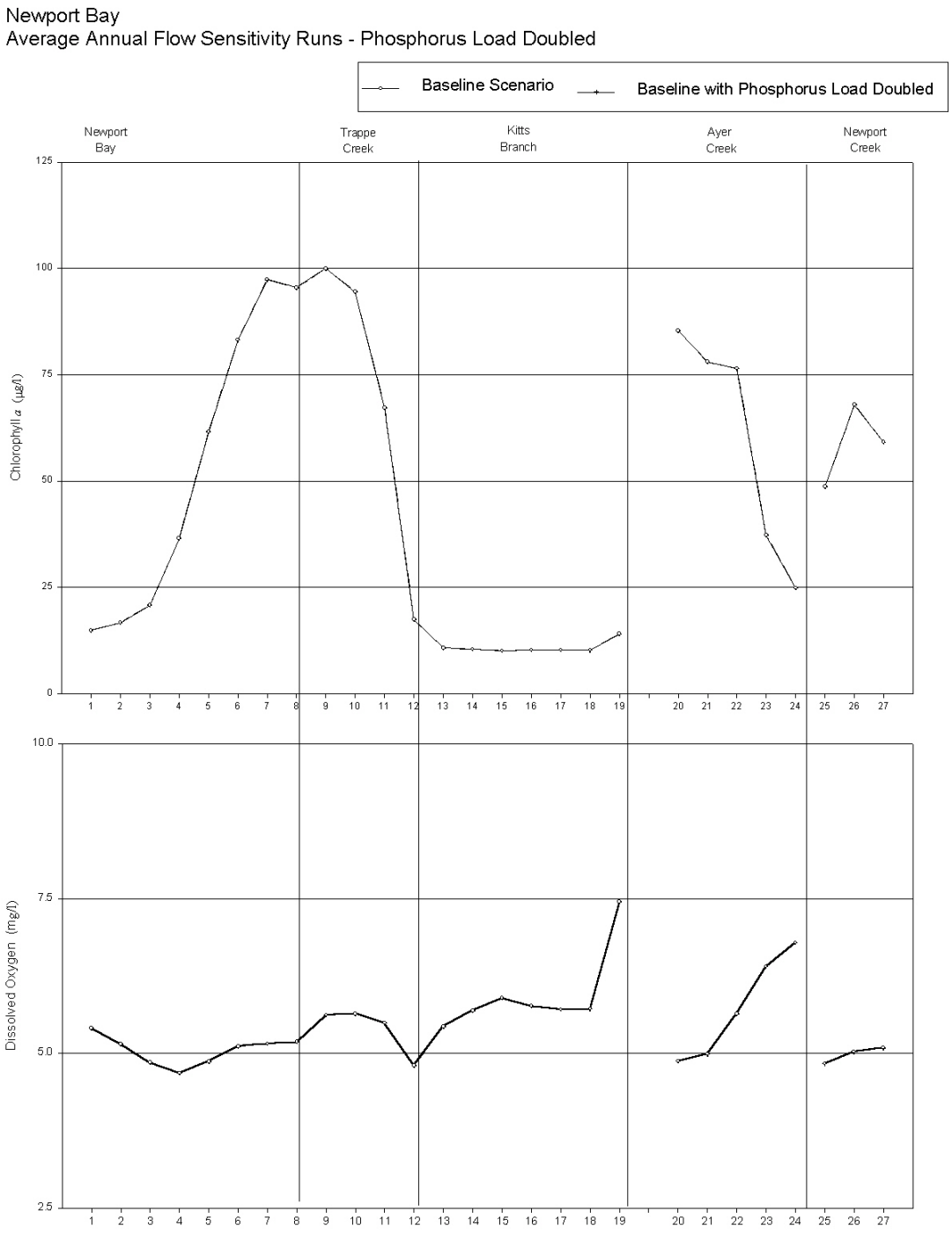

Figure B6: Sensitivity Test of Doubling the Phosphorus Load in the Average Annual Flow Condition

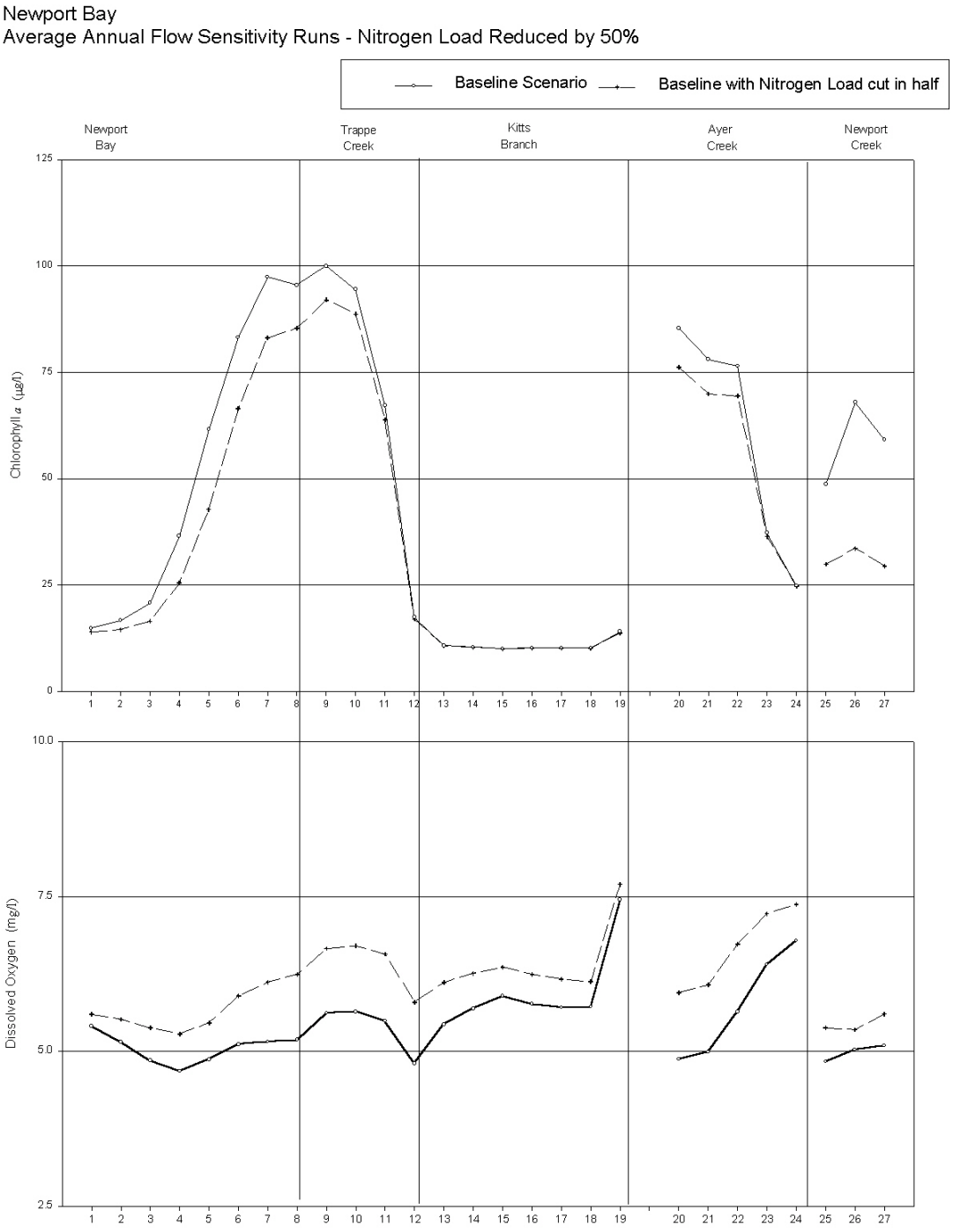

Figure B7: Sensitivity Test of Halving the Nitrogen Load in the Average Annual Flow Condition

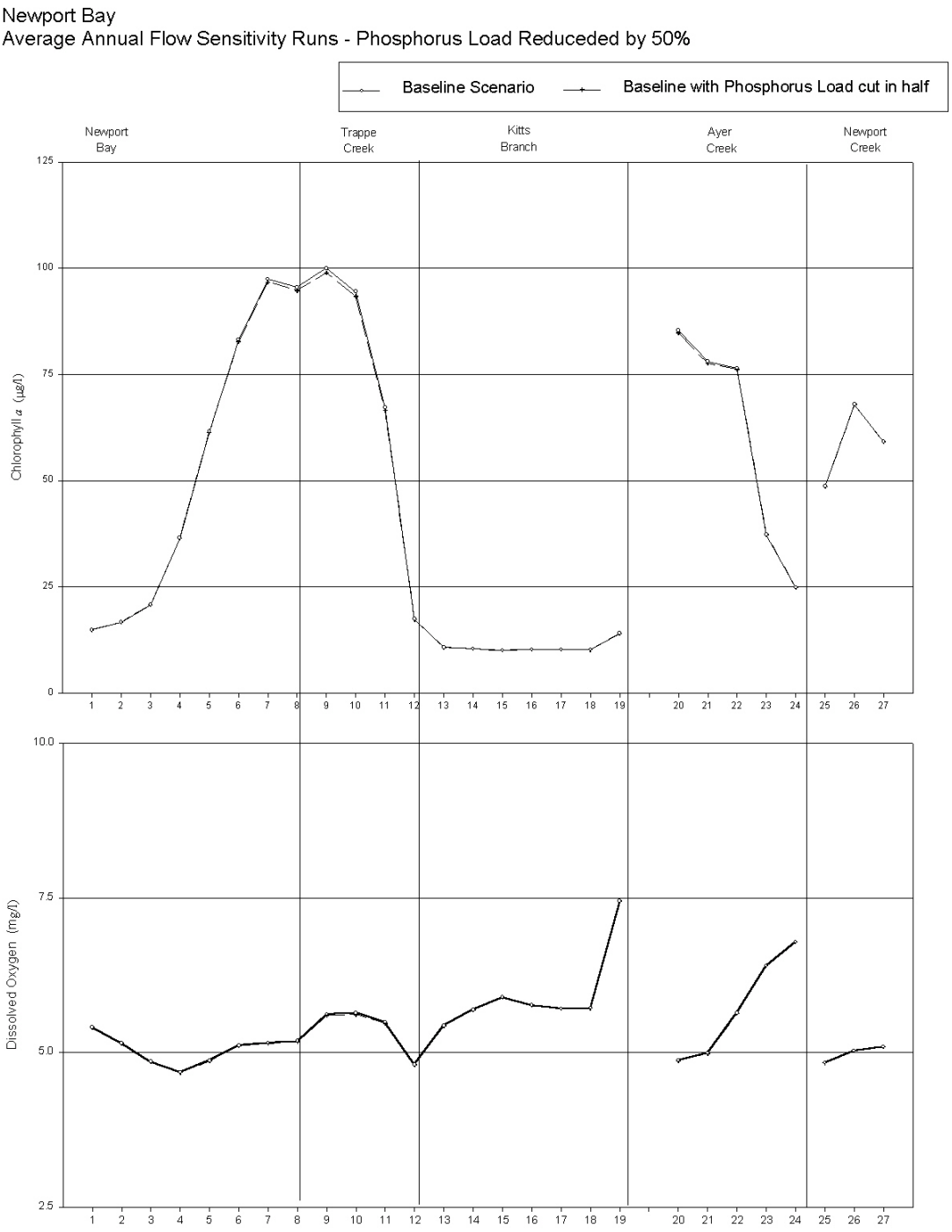

Figure B8: Sensitivity Test of Halving the Phosphorus Load in the Average Annual Flow Condition

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